

RECENT DEVELOPMENTS OF THE GEOSTATIONARY SYNTHETIC THINNED ARRAY RADIOMETER (GEOSTAR)

Alan Tanner, Todd Gaier, Pekka Kangaslahti, Boon Lim,
Bjorn Lambrightsen- JPL, California Institute of Technology

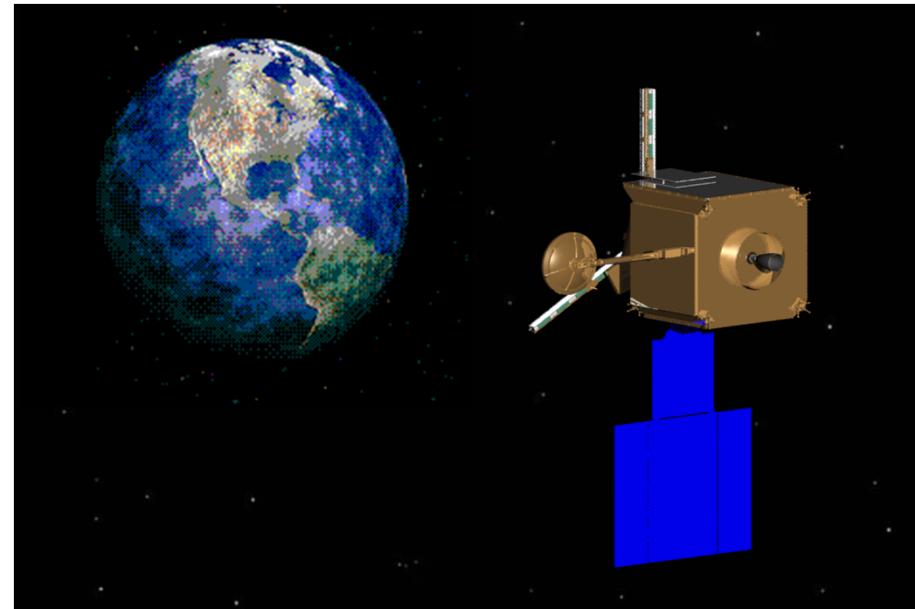
Chris Ruf- University of Michigan

Part 1:

Test results of a 180
GHz array

Part 2:

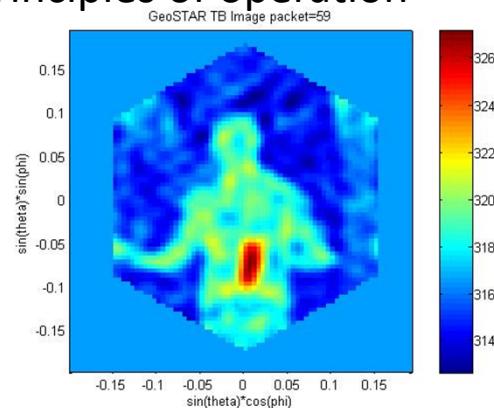
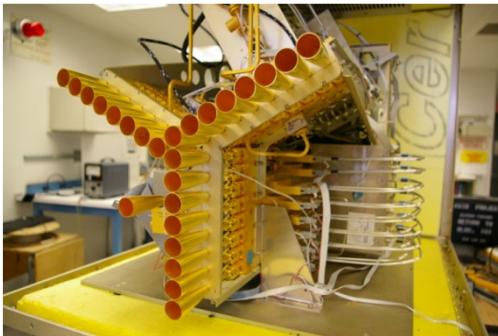
New Approach to the
G-matrix inversion



This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Copyright 2012. All rights reserved.

Background

- GeoSTAR is an instrument concept to provide high resolution microwave images of the earth from GEO.
- **2003 -2006** JPL & U Mich. developed and demonstrated working 55 GHz array.
 - Small 8-element / arm Demonstrator; Proves principles of operation



- **2007 – 2011** JPL & U Mich. Focus on ‘high risk’ elements of:
 - Correlator ASIC
 - 180 GHz receiver
 - Array mechanical & electrical design, fabrication, LO & IF distribution (AKA “tiles” or “sub-arrays”)

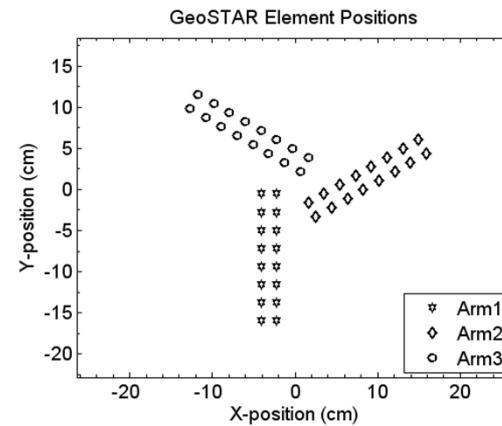
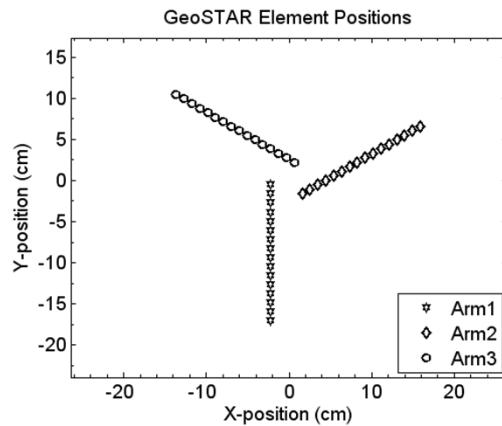
Part 1 of this talk: “Tiles”

array geometry

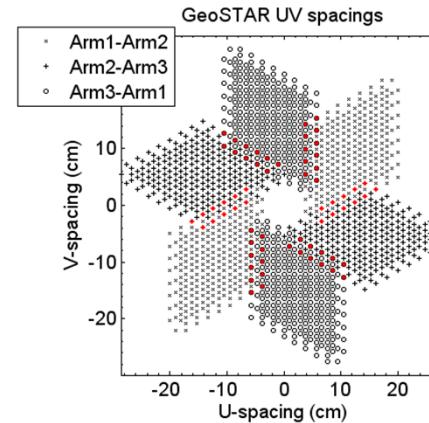
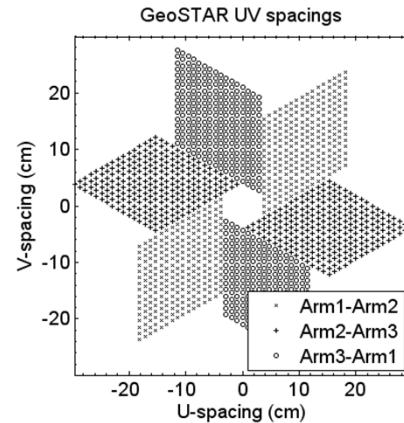
single-row of original concept;
antenna diameter < spacing;
'on-earth' antenna efficiency <
40%

two-row; 3 x more gain,
but still not ideal

element positions:



UV coverage:



Array Geometry (cont.)



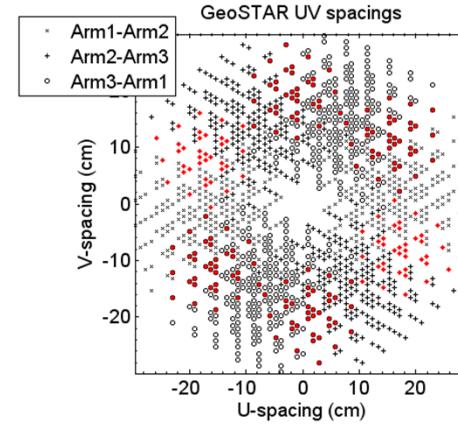
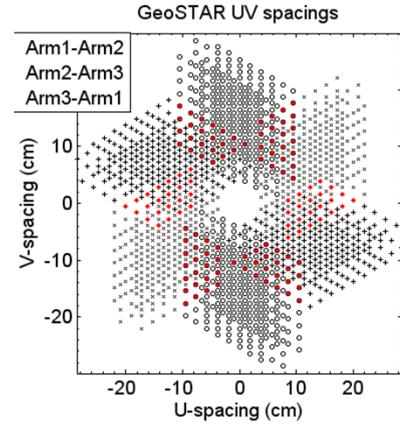
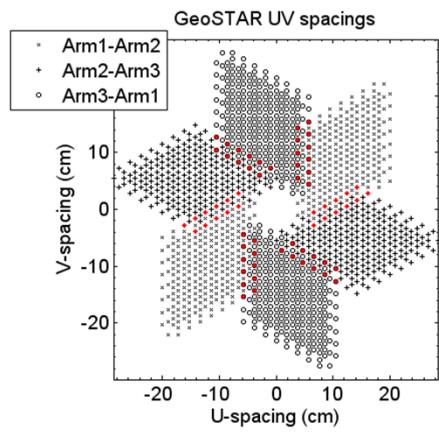
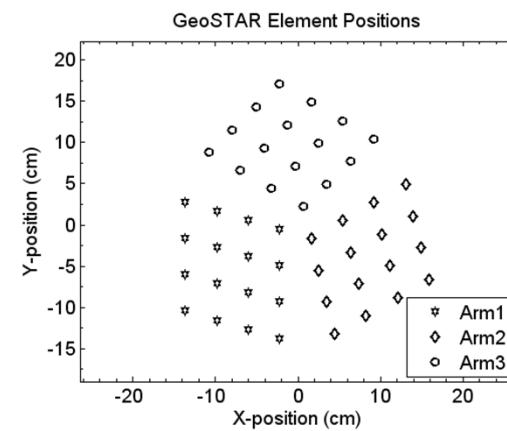
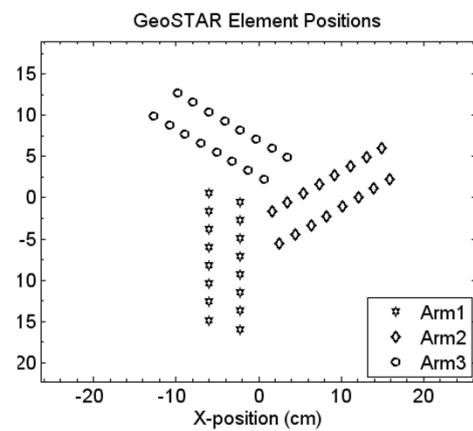
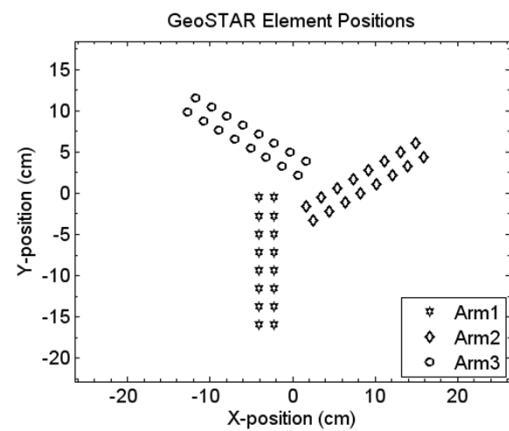
two-row



extended
two-row

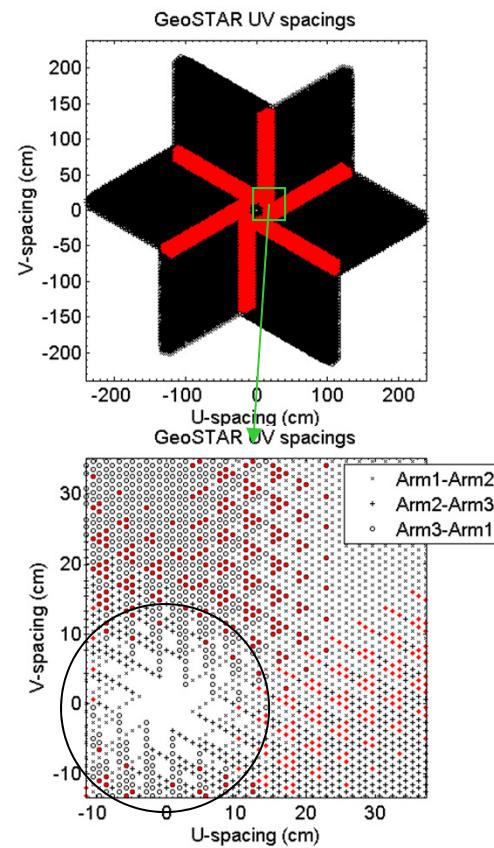
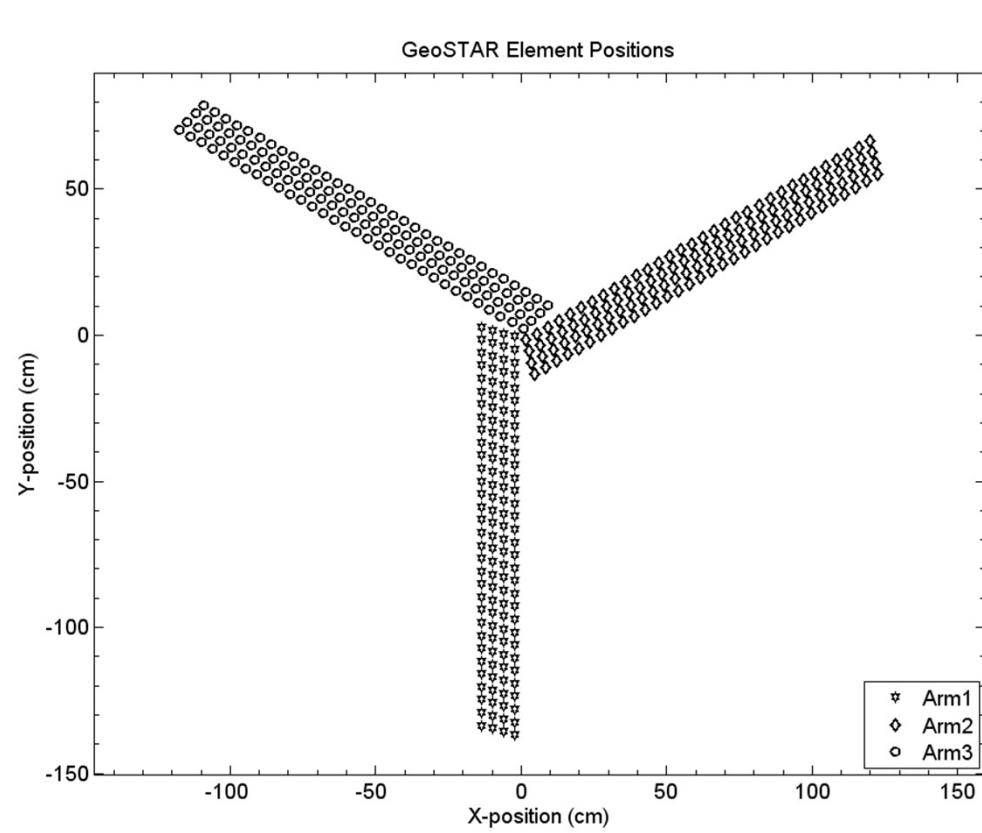


four-row array; 4x more
room = enough to
optimize gain

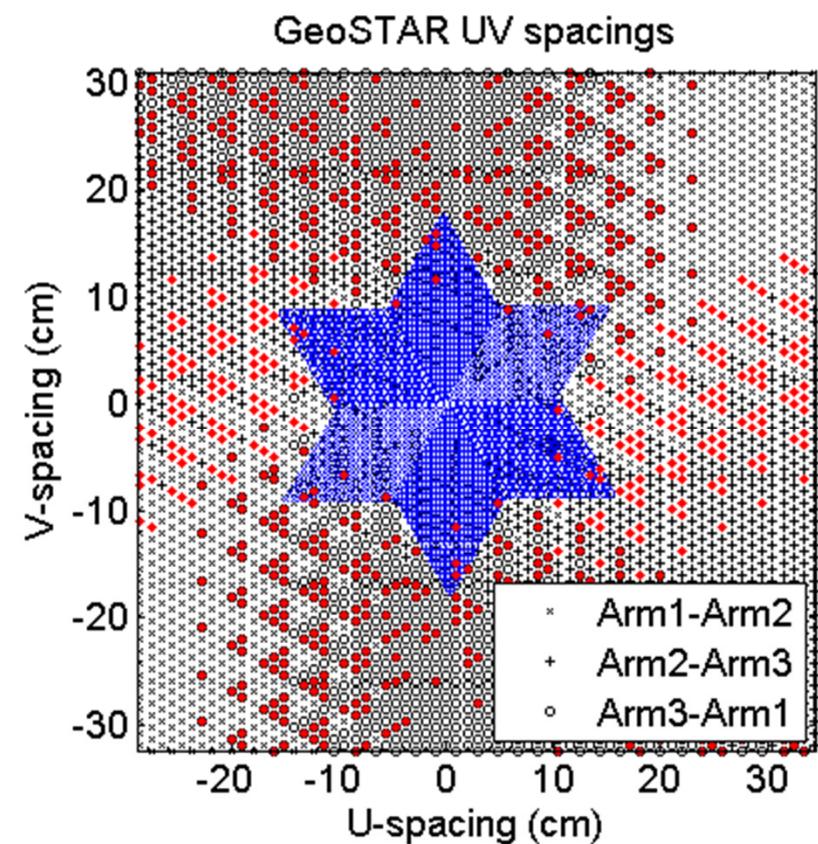
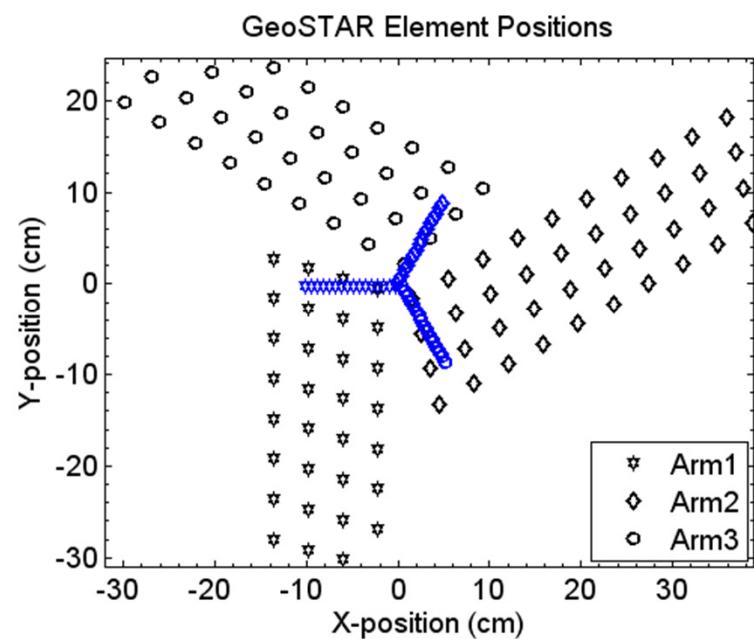


Bigger picture...

- For $r > 12$ cm, UV plane is sampled completely by 4-row
- The only ‘missing’ UV samples are all within $r < 12$ cm of the array

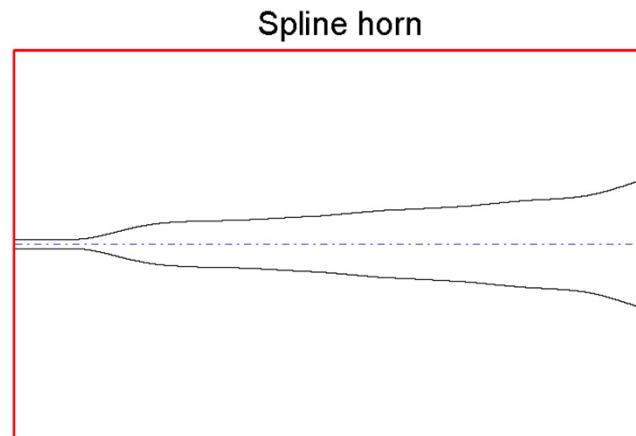


The ‘missing’ samples will be measured with separate array



Antenna design

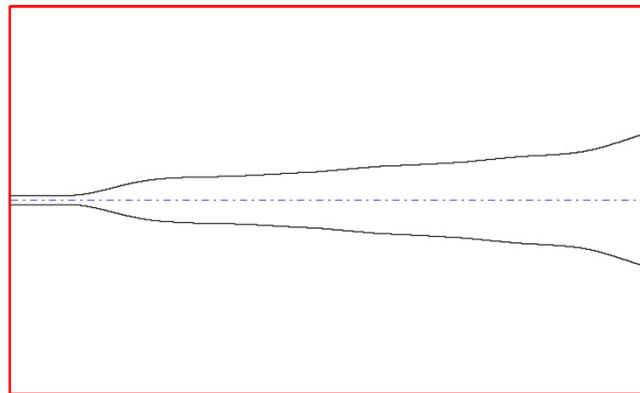
- Spline fitting algorithm was applied by W. Imbriale
- Approach iterates spline profile parameters to seek “optimum”
- “Optimum” proved to be a tricky measurement for GeoSTAR, as neither beam efficiency, sidelobe level, nor peak gain were adequate specifications
- Study revealed delicate balance between array spacing, antenna gain, and (in particular) beam *shape* when optimizing for maximum synthesized FOV and sensitivity (ΔT)
- Best solution (so far) found by seeking a least squares fit to a truncated Airy disk



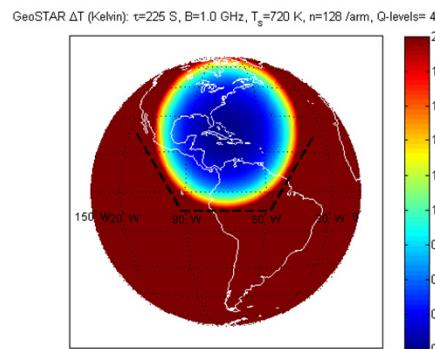
Balances antenna shape & gain *very carefully* with array spacing

- Very good match w Airy pattern
- Scales nicely from 166 GHz ~ 183 GHz

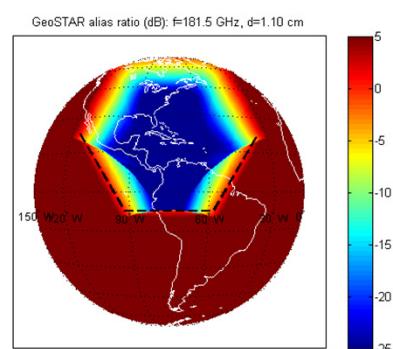
Spline horn



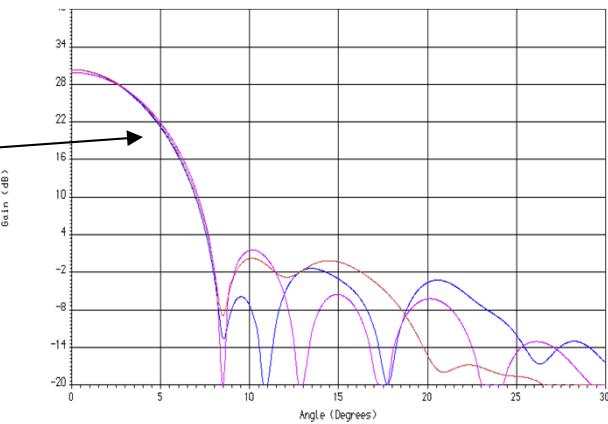
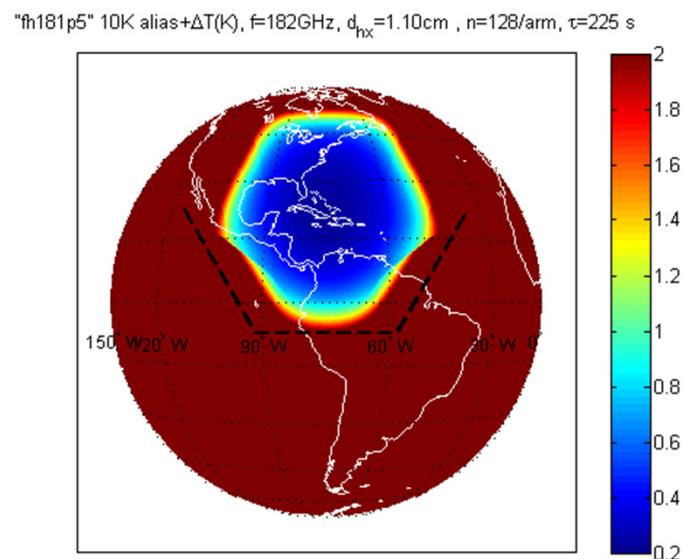
sensitivity



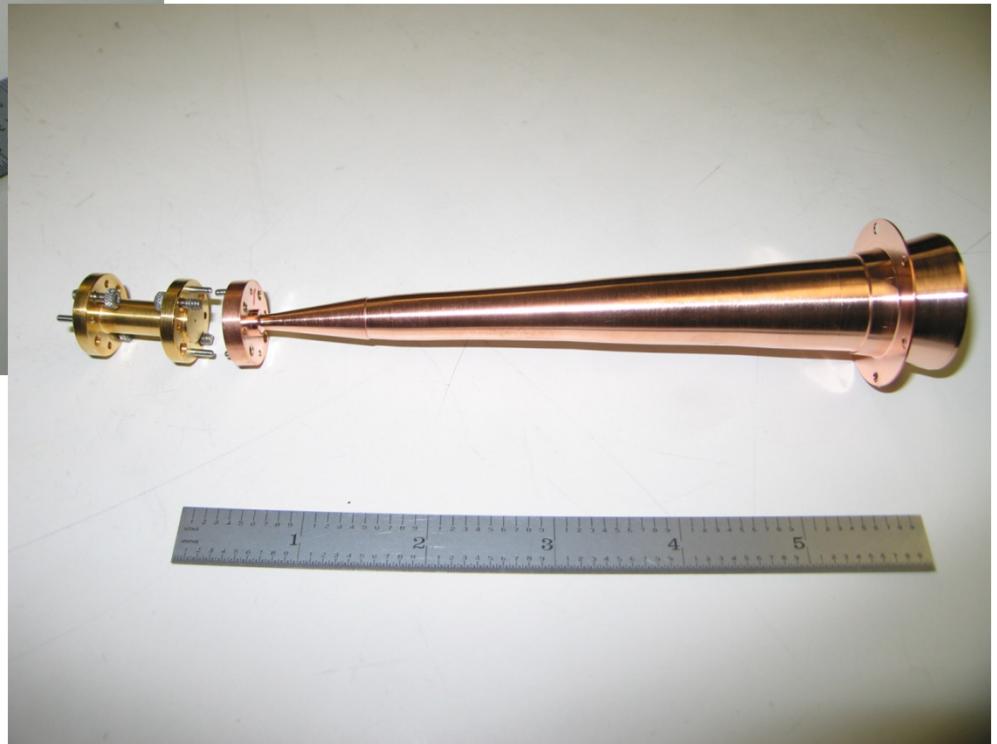
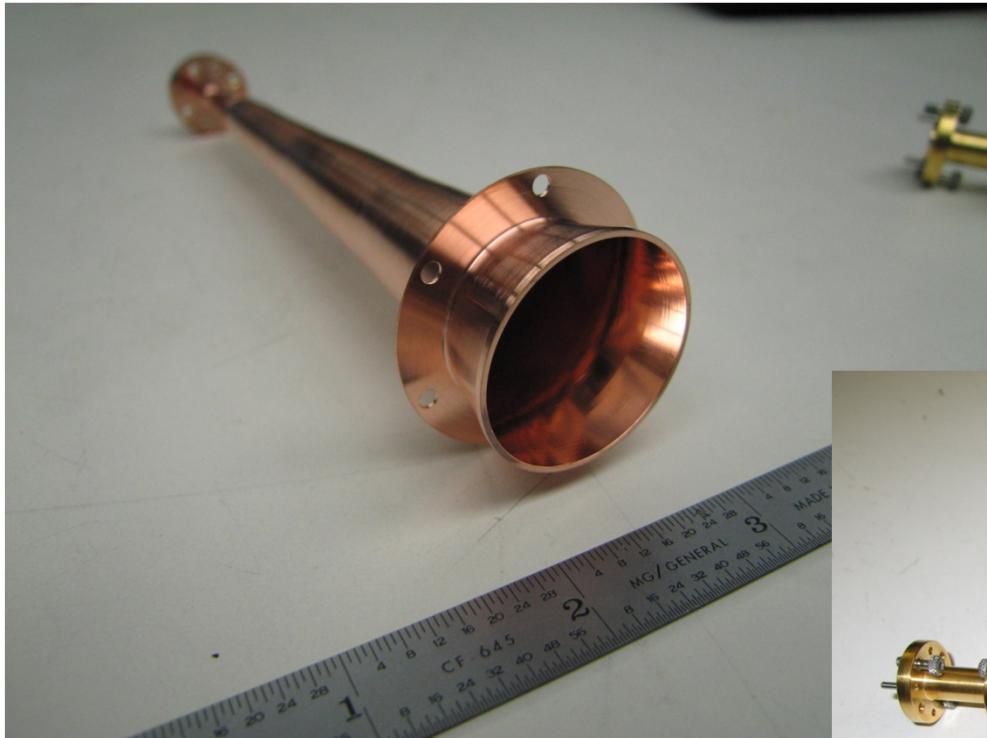
+ alias rejection



=

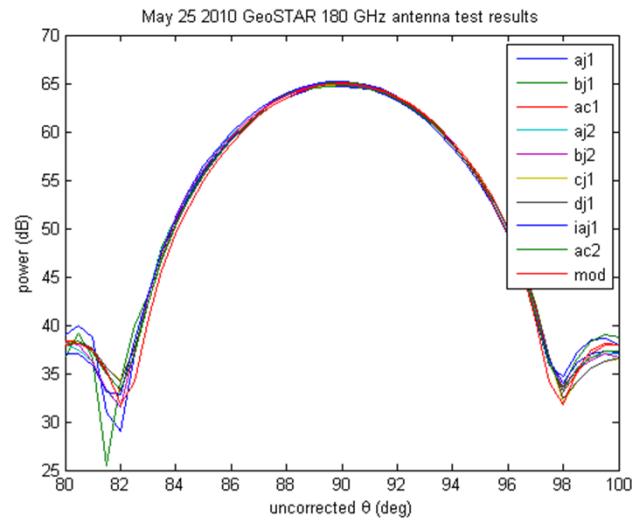


Fabricated horn test article

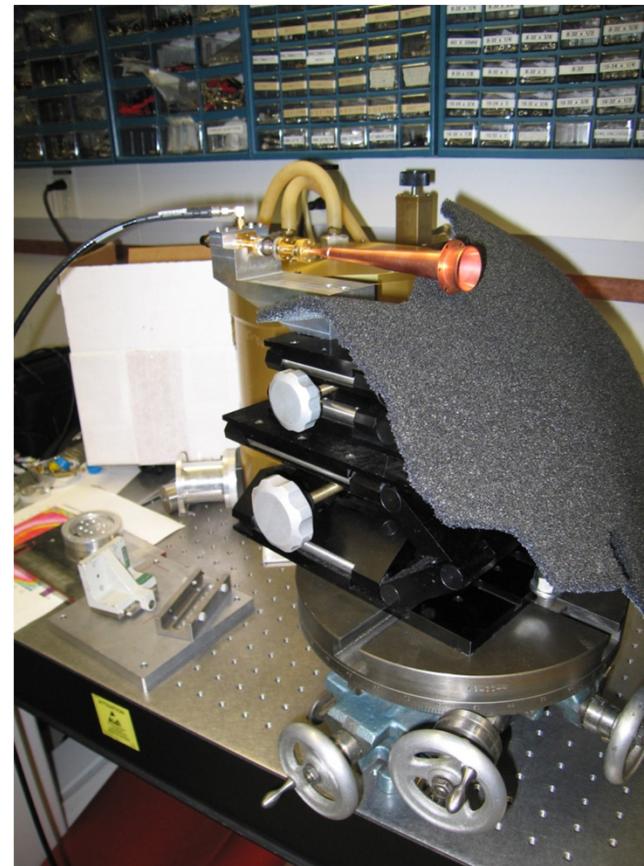
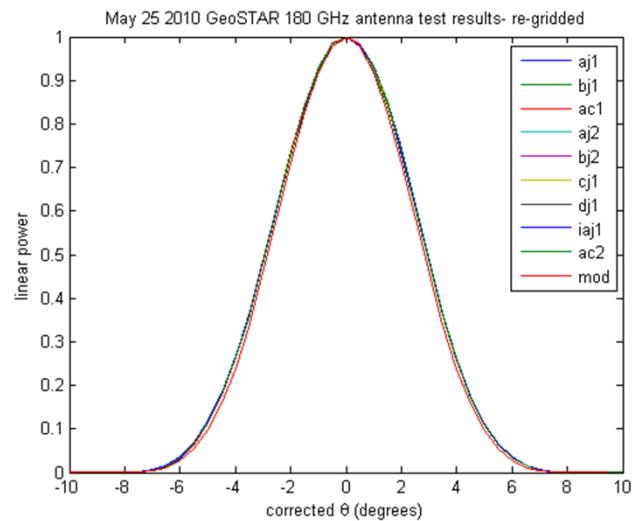


horn test April 2010

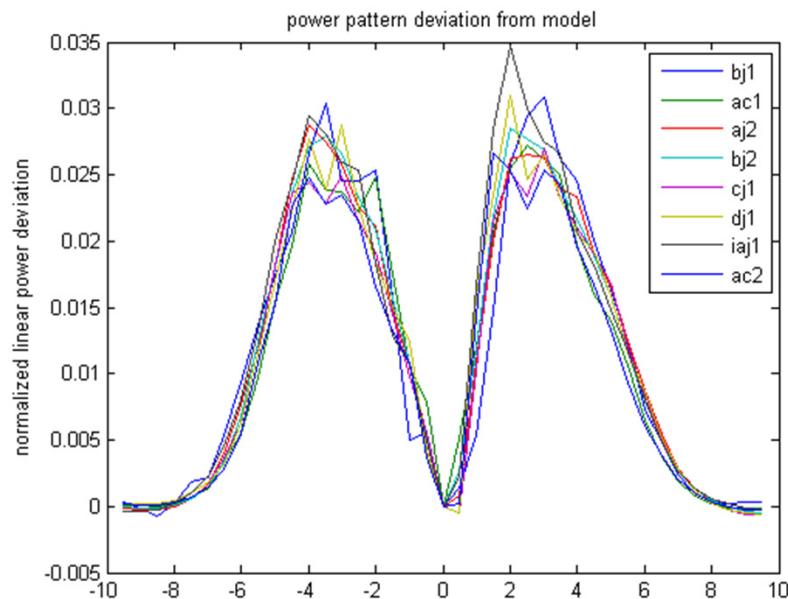
**log plot of
raw data
(4 horns,
2 test ea.)**



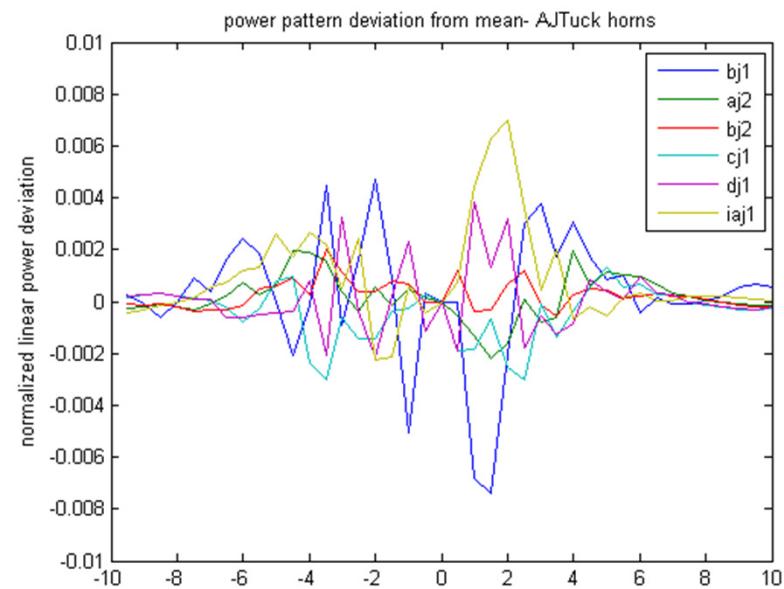
**linear
plot of
aligned
data**



measured antenna pattern deviations



linear deviation from model
~2% or 0.1 dB peak error



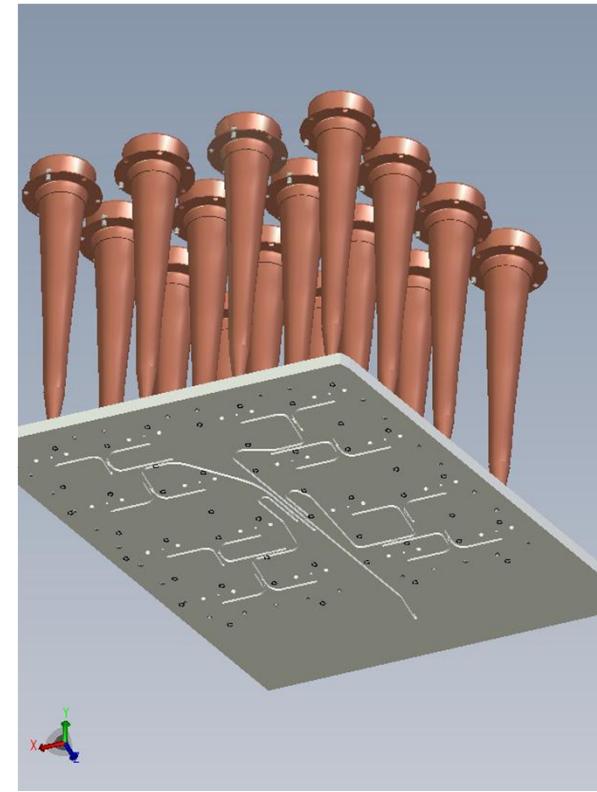
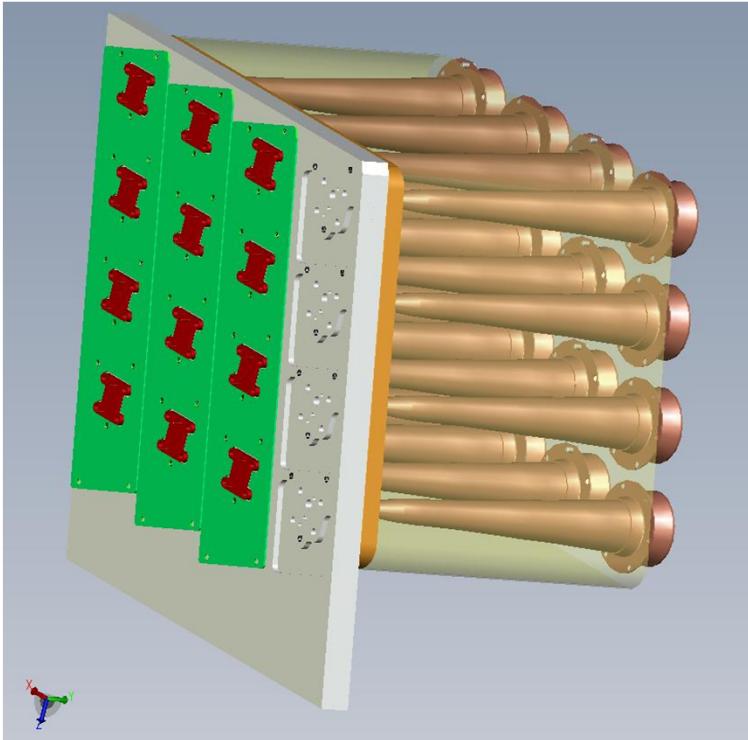
linear deviation from mean
~0.4% or 0.01 dB peak error!

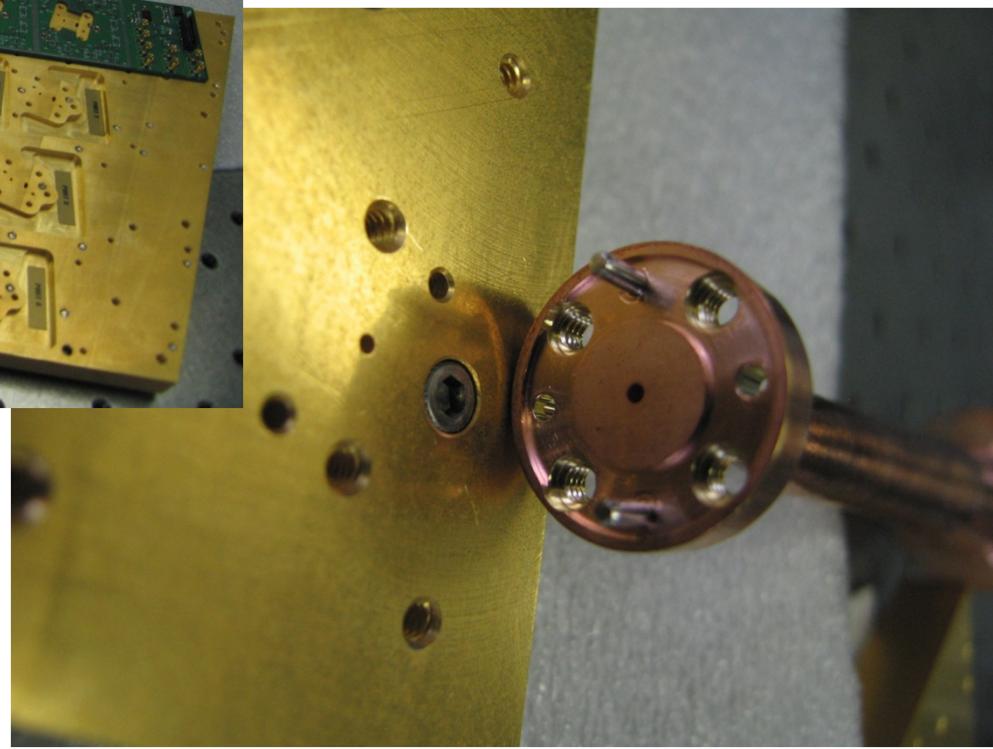
EXCELLENT Results! Will make calibration MUCH easier!

GeoSTAR manifold

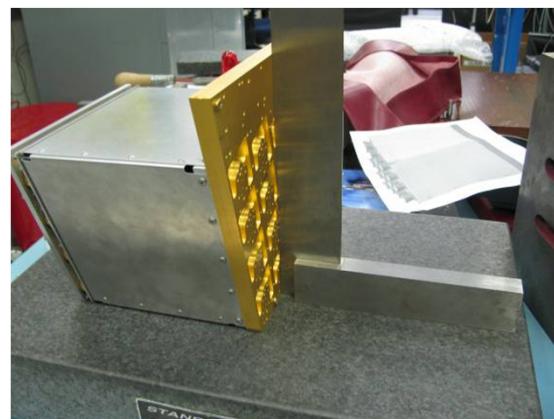
Manifold is structural basis of GeoSTAR sub-array which integrates:

- WR10 Local Oscillator distribution
- WR5 “twists” (+/- 60 degree and 0; unique to ea array)
- WR5 circular transitions
- all interfaces for IF PCBs, MIMRAM modules, horns, LO

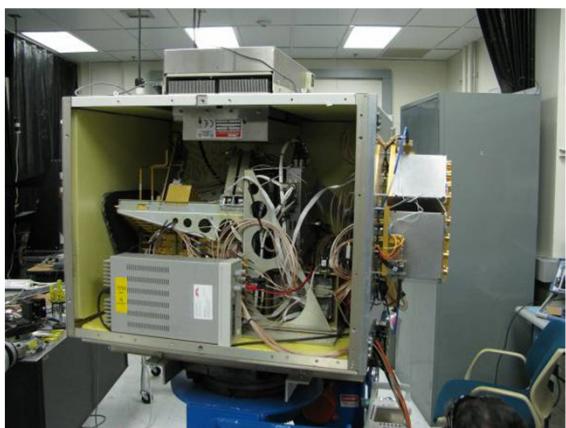
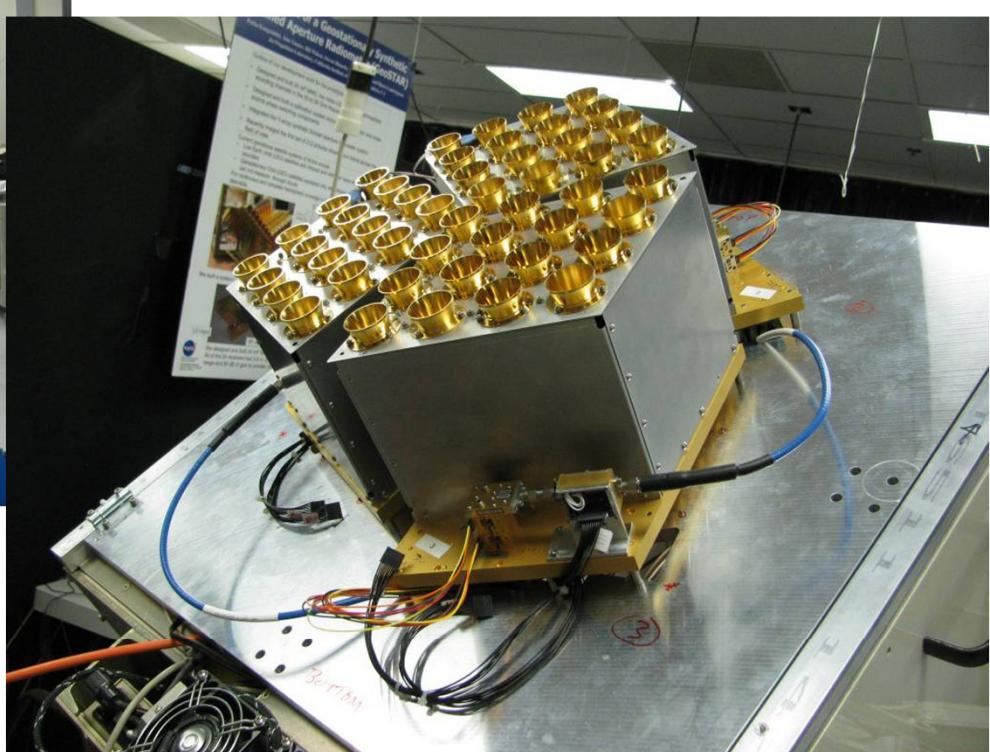




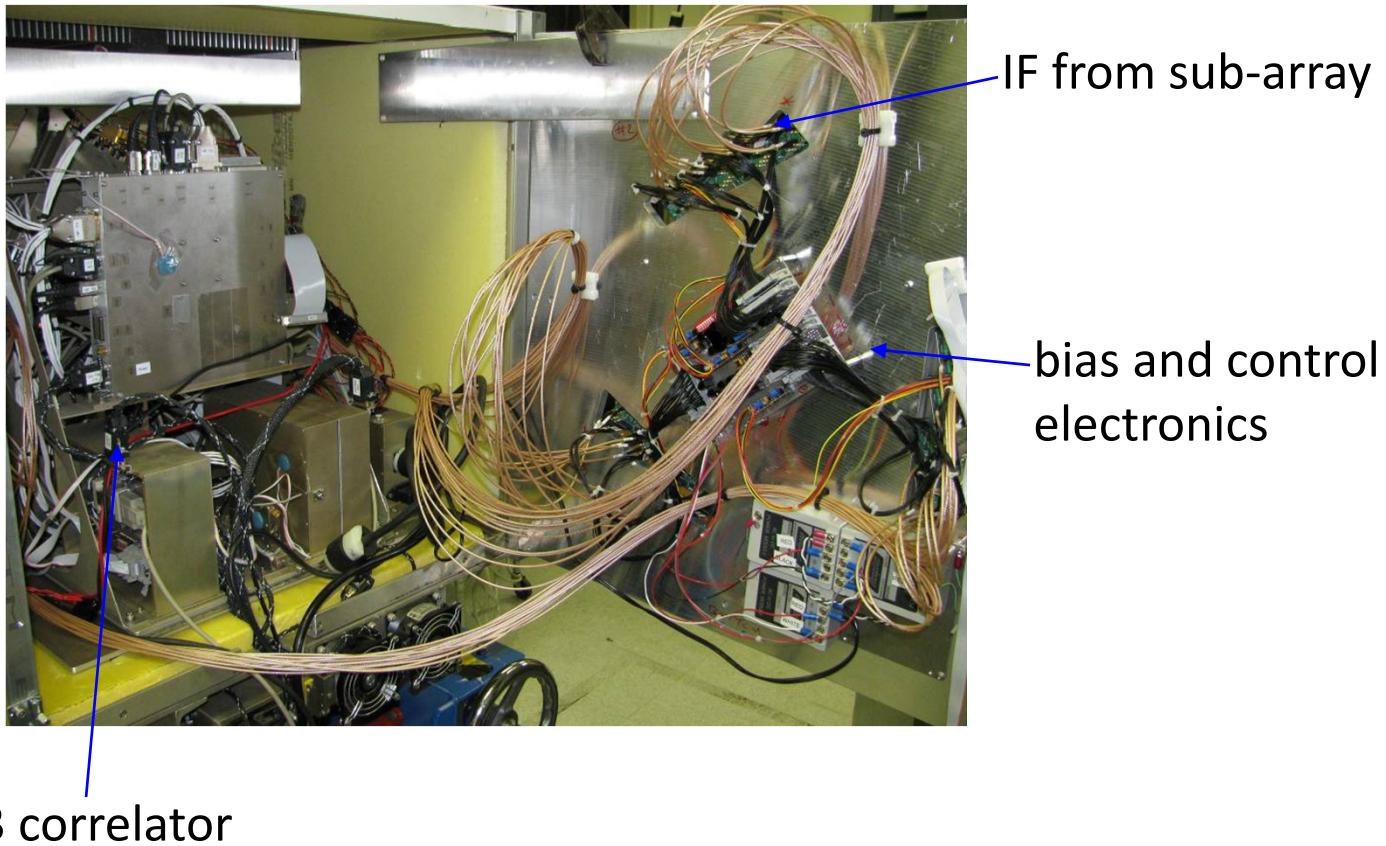
Sub-array Modules- horn & manifold integration & alignment



Sub-array Modules- Integration w IIP-03 testbed



IF cabling to IIP-03 system and bias control



Sub-array Modules & System Tests- LN2 Calibration



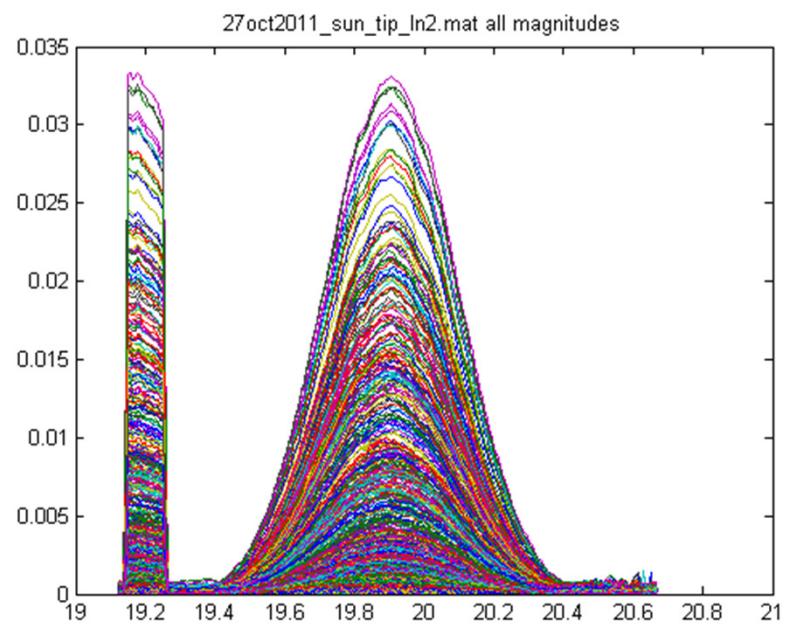
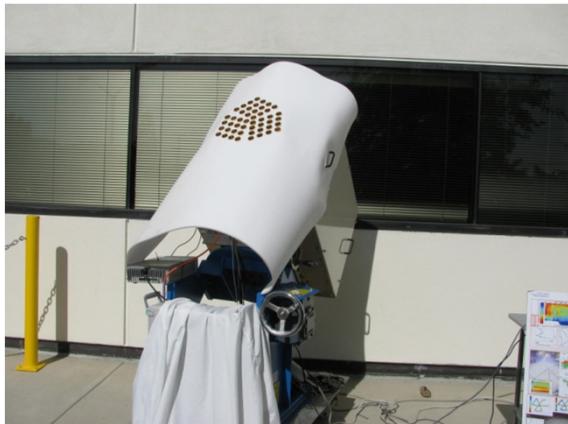
October 24, 2011

LN2 Y-factor

Receiver noise:

el	arm-1	arm-2	arm-3
1	492	540	431
2	1567	445	405
3		525	429
4	547	563	481
5	757	481	980
6	676	578	1378
7	477	2327	
8	3401	358	1176
9	408		
10	598	1379	681
11	435		
12		1286	
13	8066	809	4409
14	527	996	
15	583	629	1658
16	1218		484

Sun Transit Test



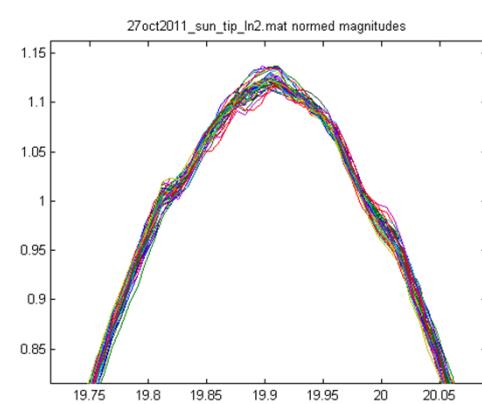
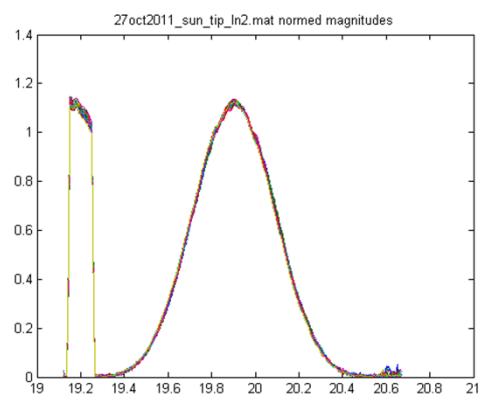
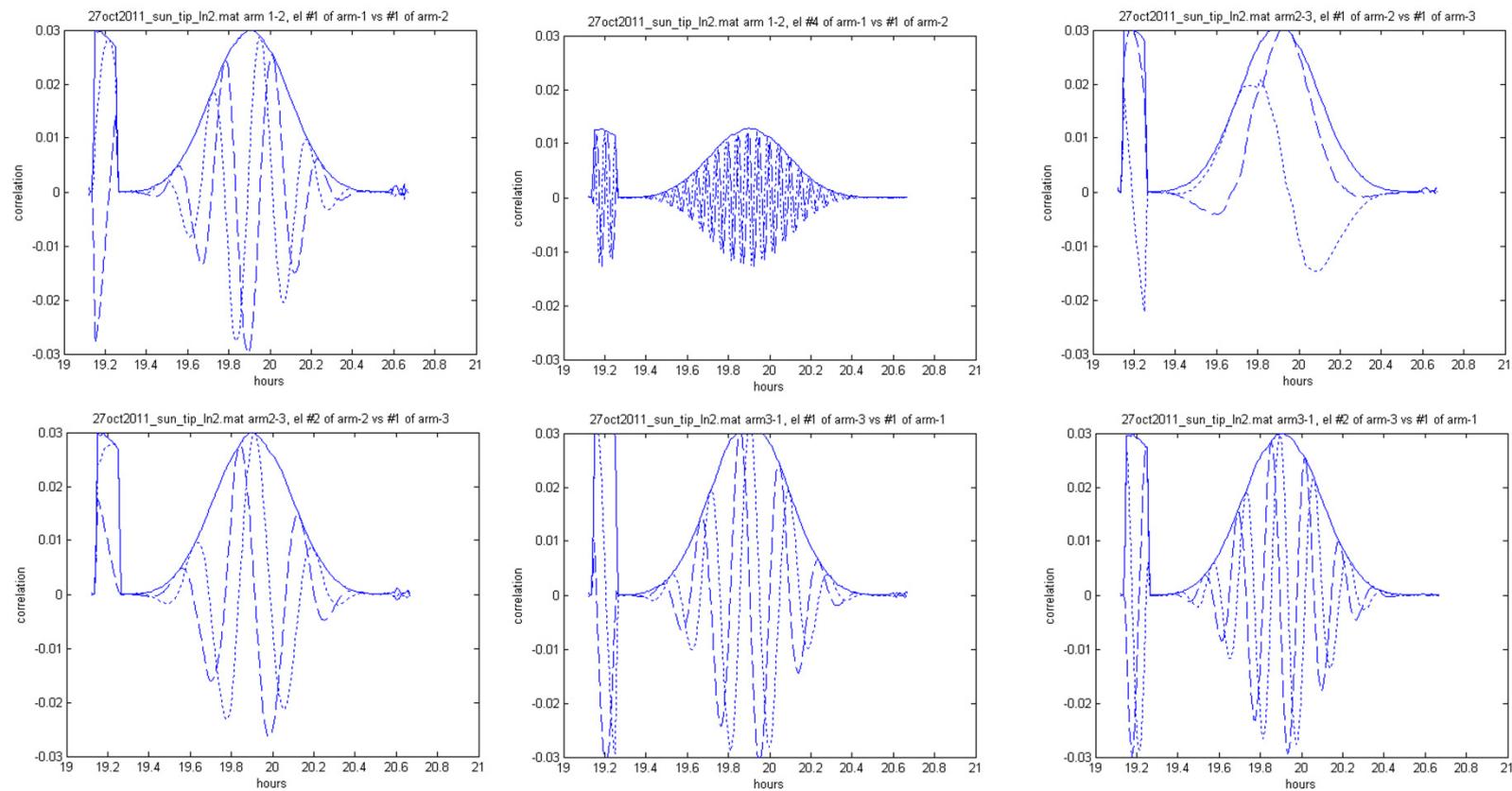
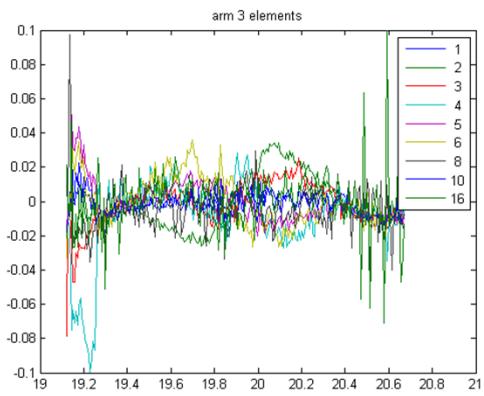
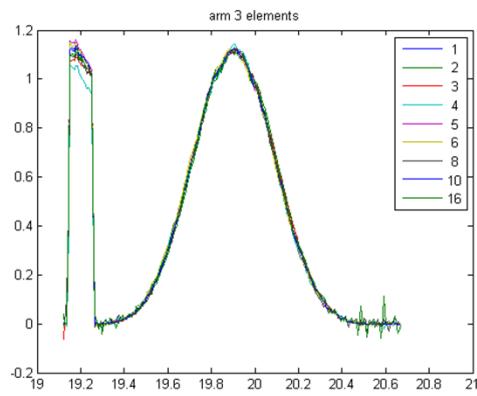
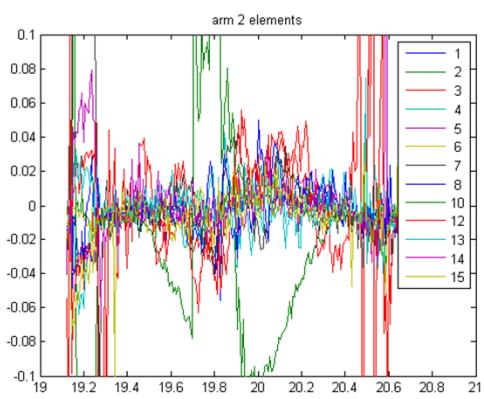
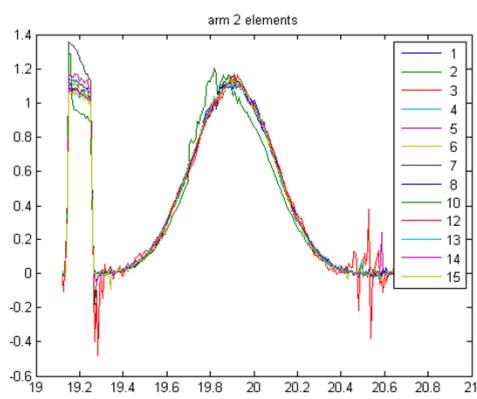
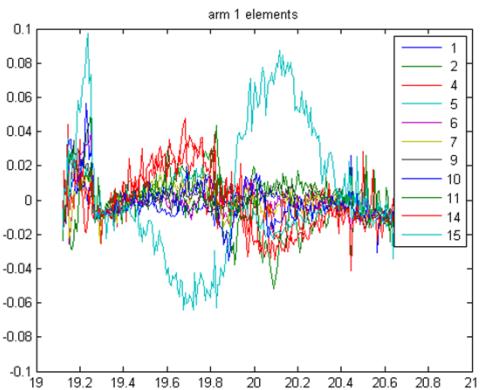
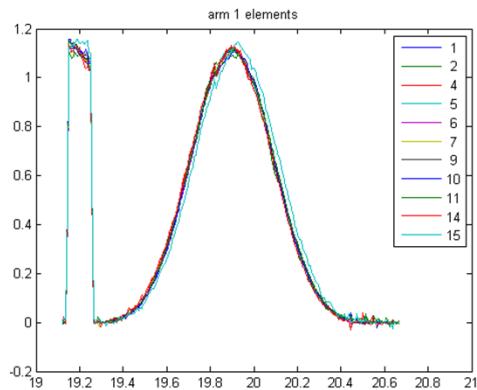
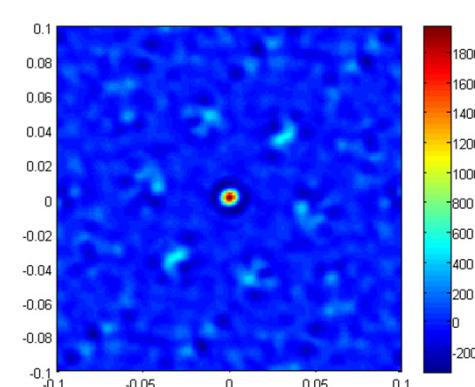
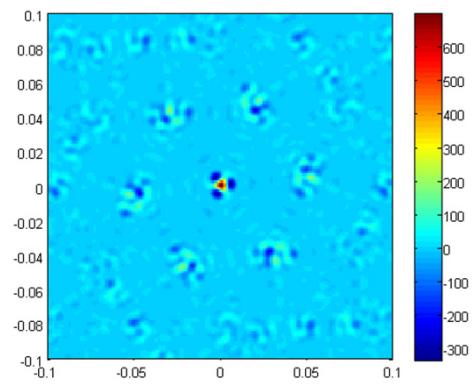
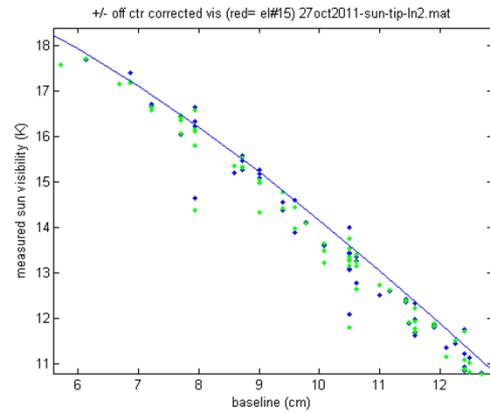
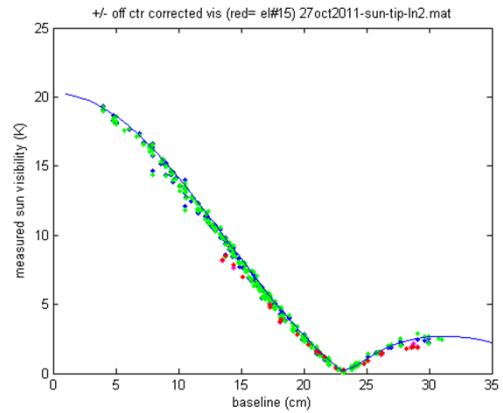
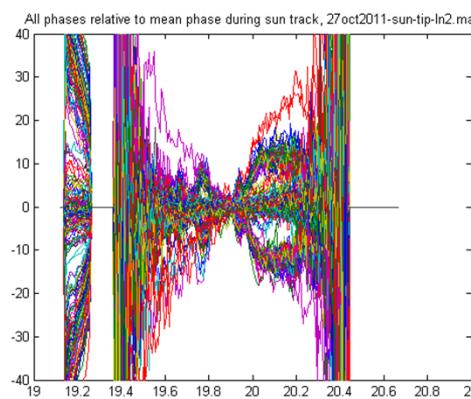
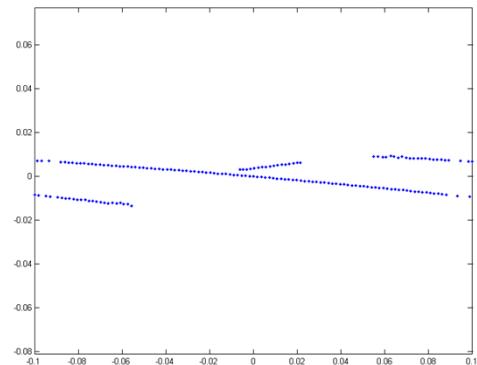


Figure 4: Sample correlations with quadrature components (dashed and dotted traces) and magnitude as in Figure 1.

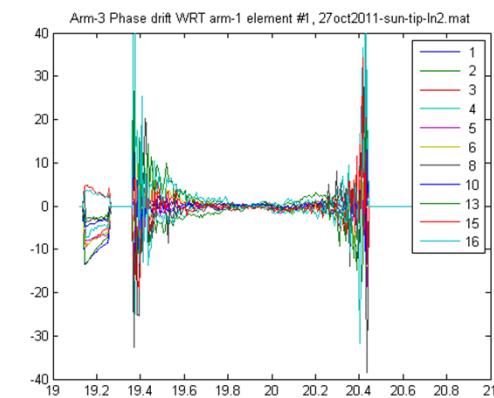
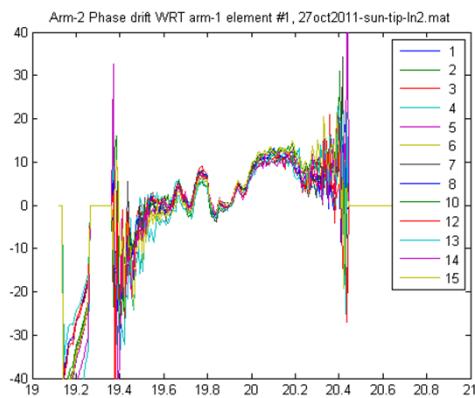
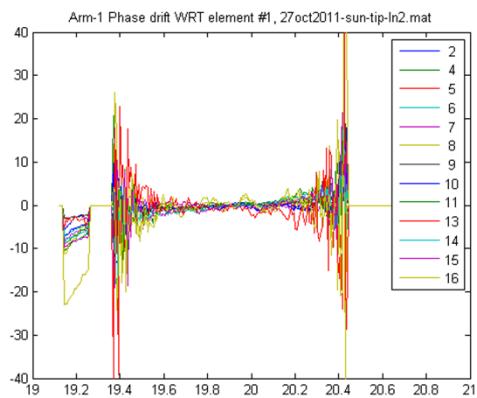






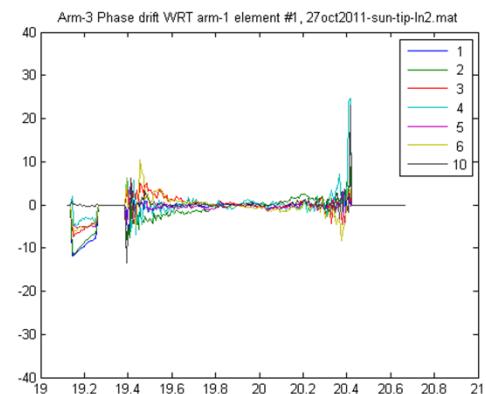
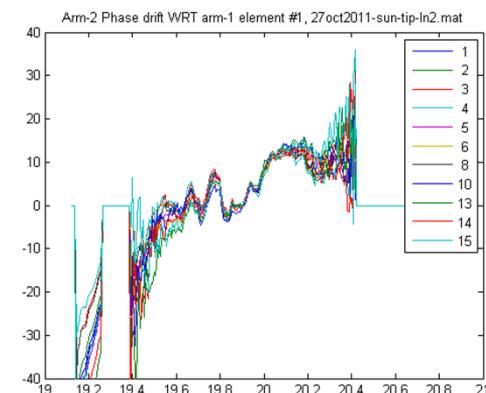
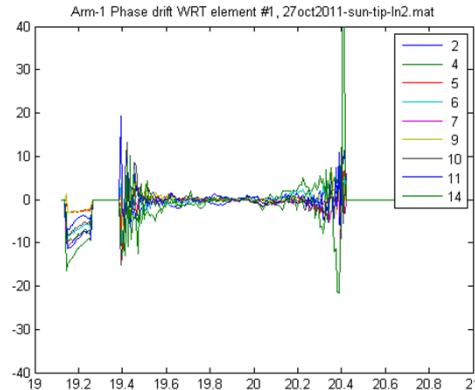


Sun positions as determined by fit to GeoSTAR

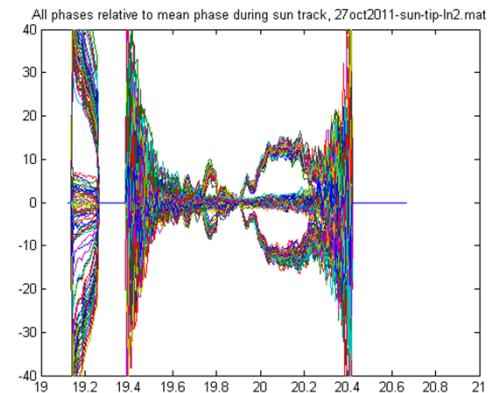
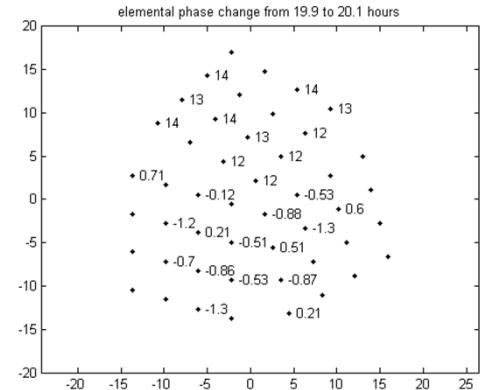
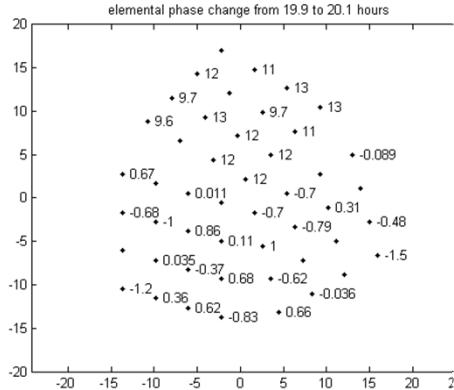


(a)

Figure : Phase change from 19.9 and 20.1 hours, revised with better sun position estimate (a), and then increased threshold of 0.01 correlation magn

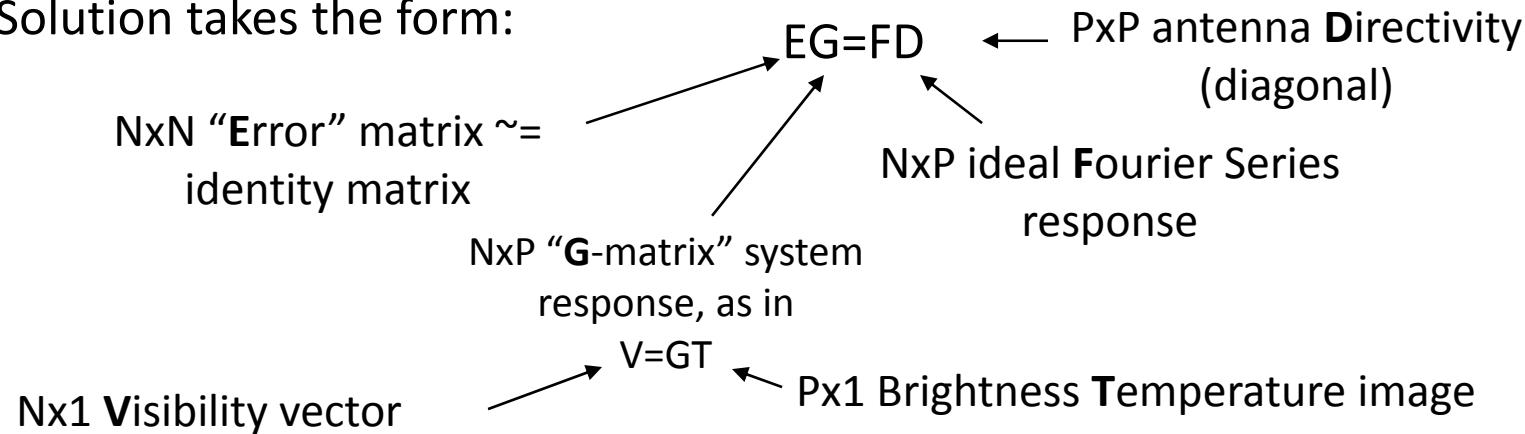


(b)



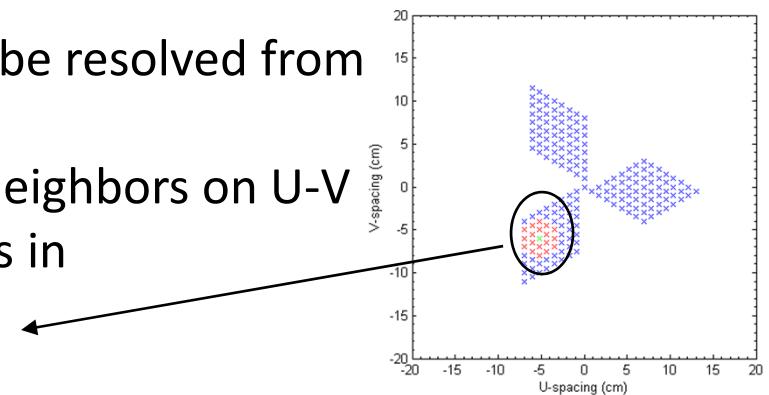
PART 2: New G-matrix approach

- New image synthesis technique developed to ease mechanical tolerances by mapping non-ideal response into a mathematically ideal response prior to inversion using an “E-matrix”.
- Solution takes the form:

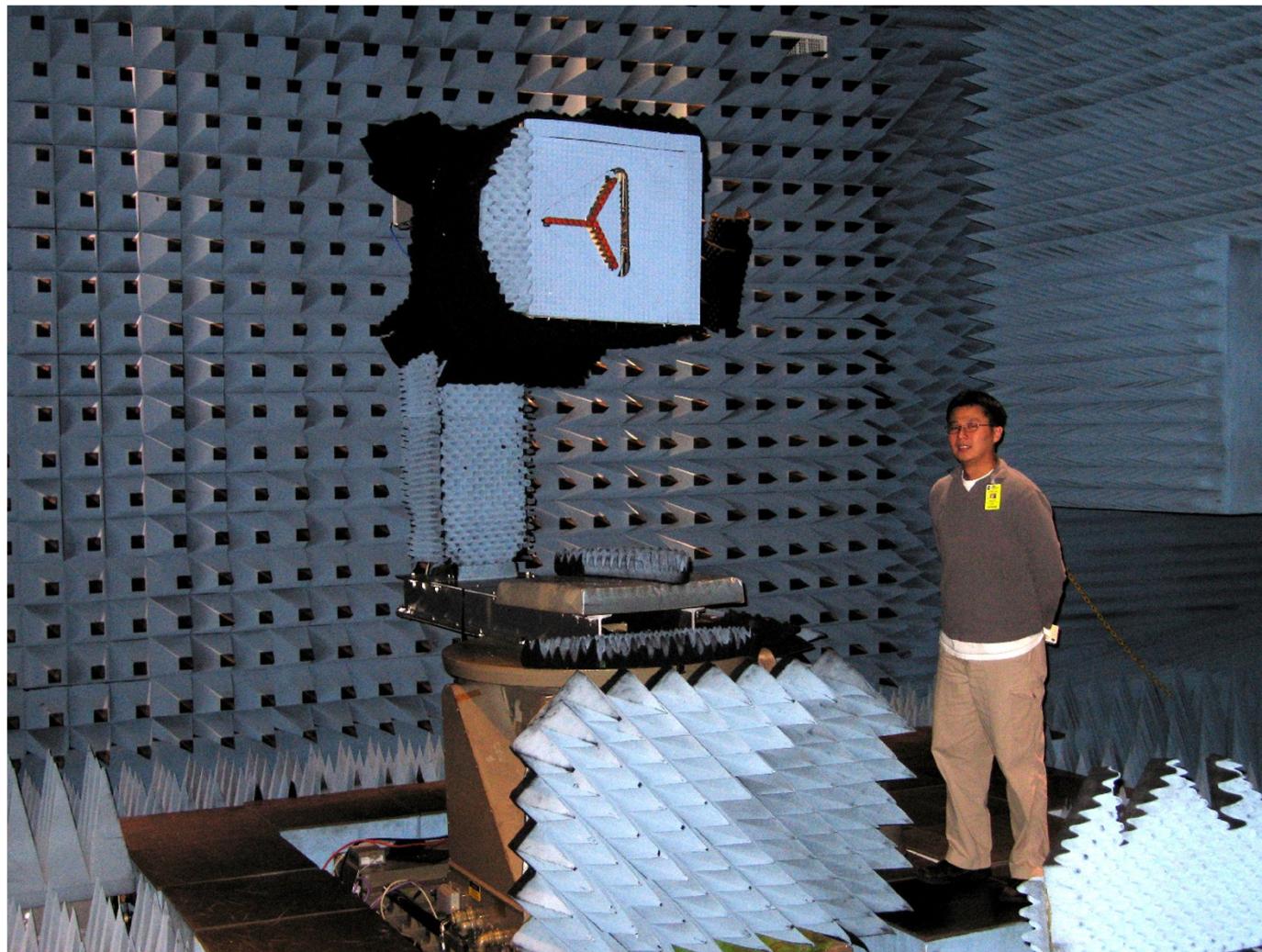


- The E-matrix has the advantage that it can be resolved from sparse measurements of G.
- Key is that mappings only involve nearest neighbors on U-V plane. This reduces size of matrix inversions in

$$E_n = F_n D G_n^t (G_n G_n^t)^{-1}$$



Boon Lim 2006



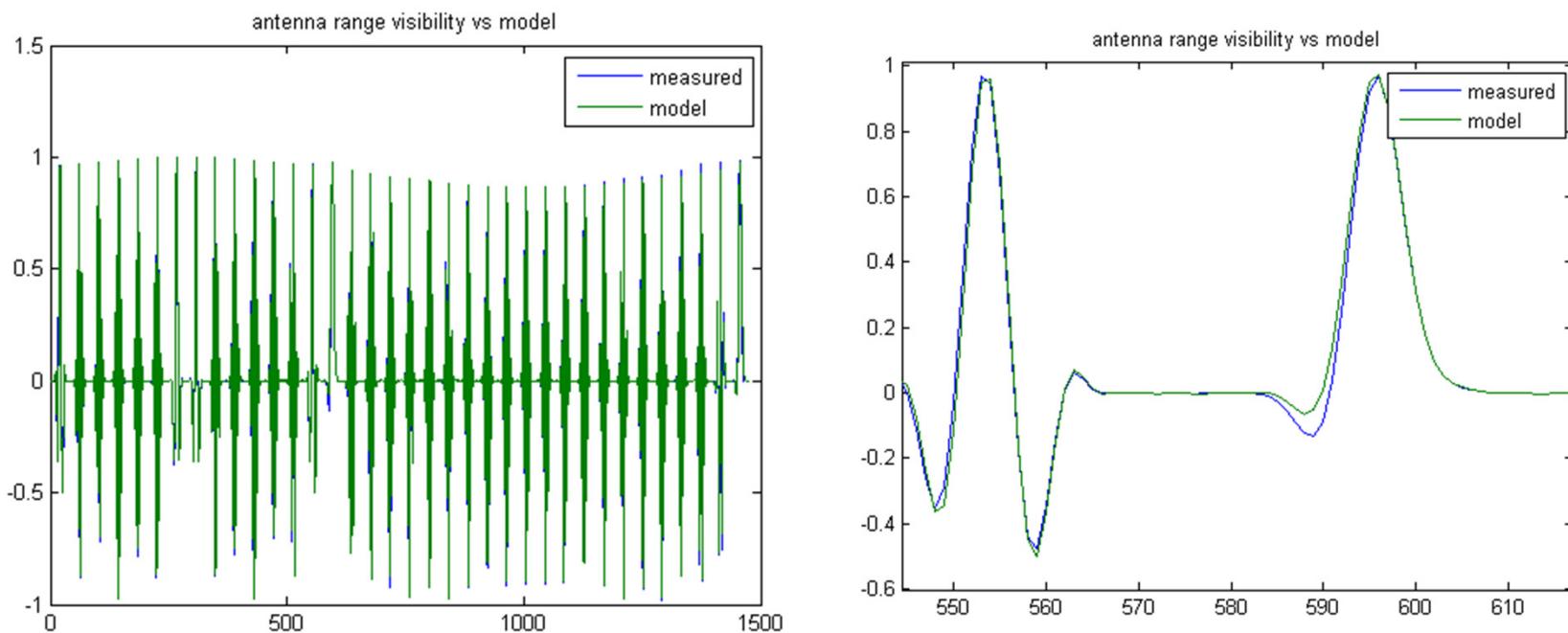


Figure 2: Example of September 30, 2005 antenna range test of GeoSTAR. The real part of the correlation between antennas #1 and #9—which are at the ends of the array arms—is plotted versus sample number on two scales. The blue curve is the measured response and the green curve is the model response. This test sequence lasted about 15 hours. The right hand figure is an expansion of the left hand figure.

Figure 3a: $N_n \leq 2$, baseline test case

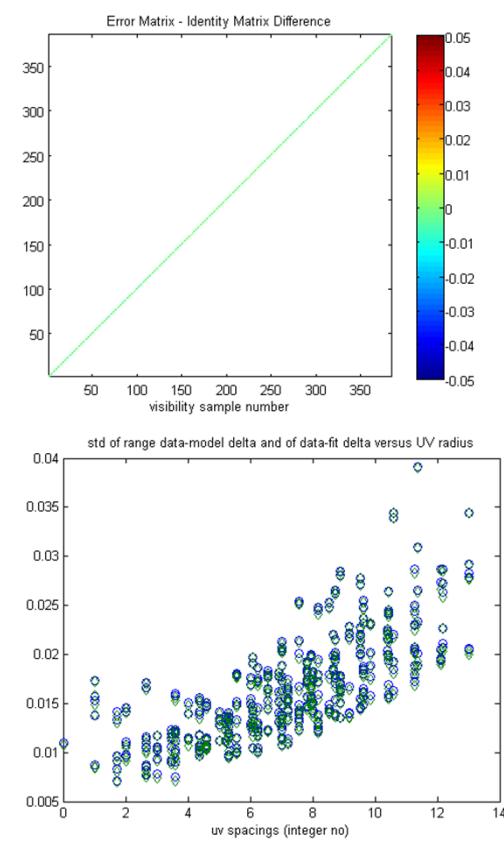
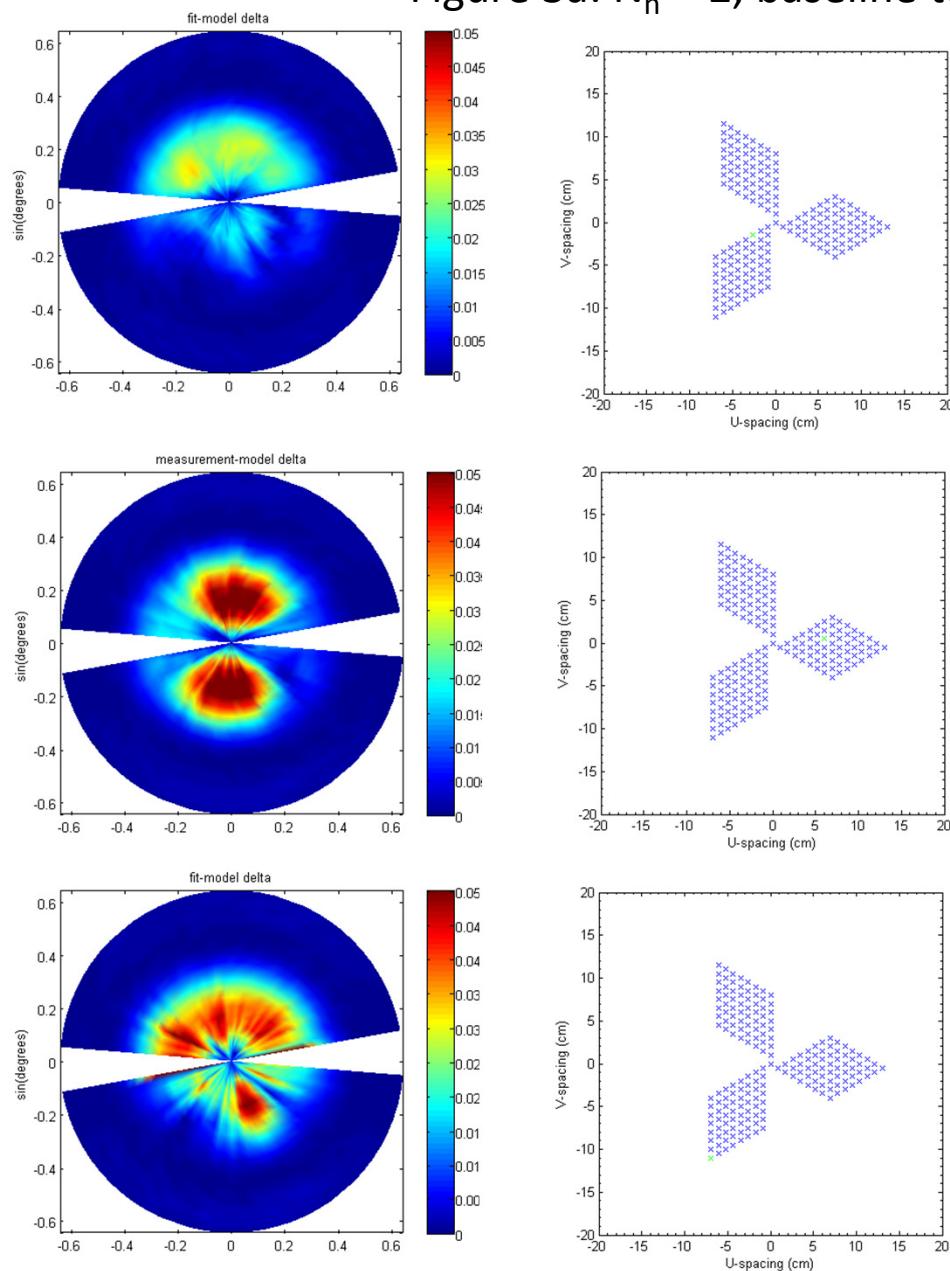


Figure 3b: $N_n \leq 14$, smallest correction with nearest neighbors

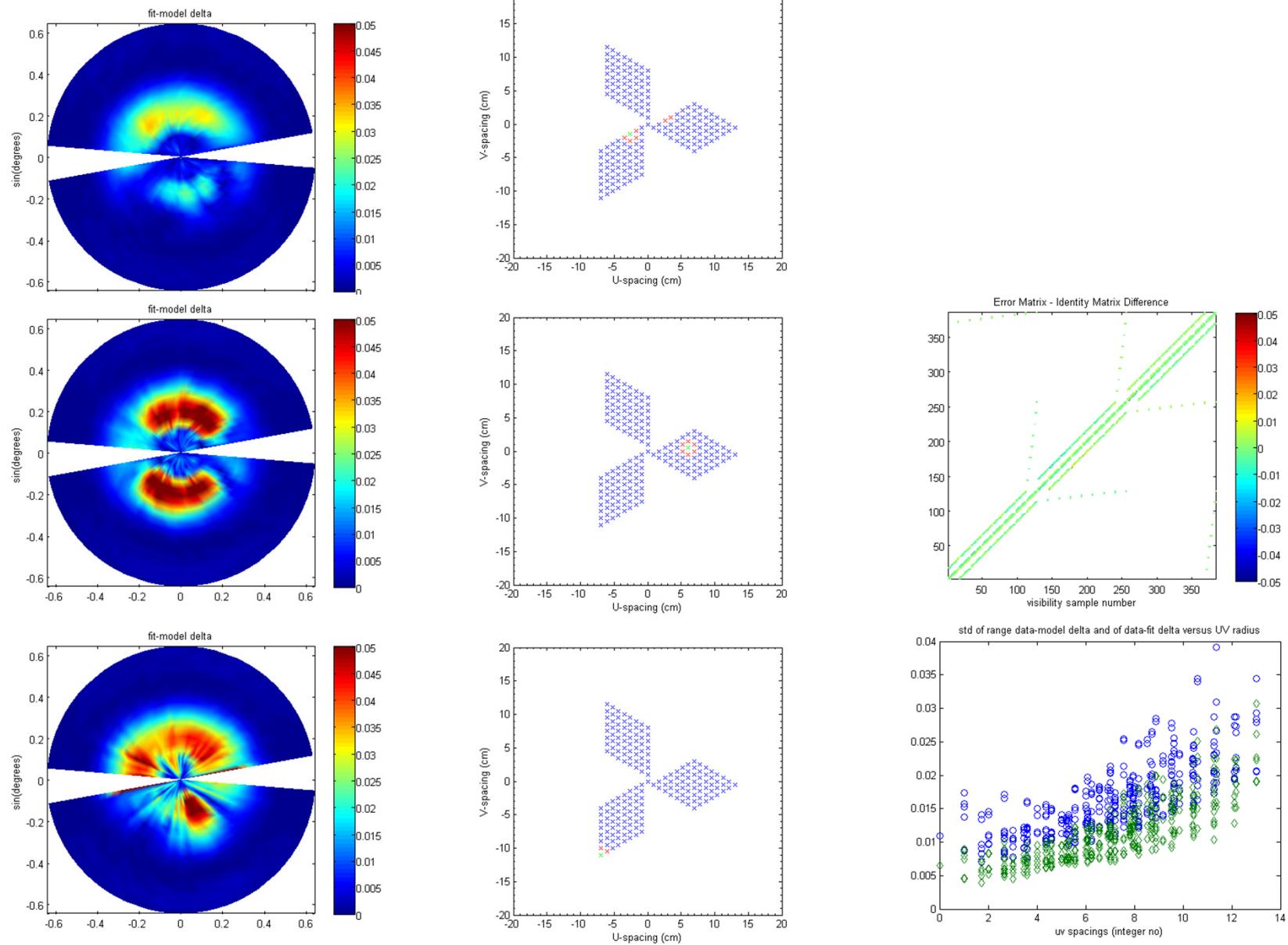


Figure 3c: $N_n \leq 38$

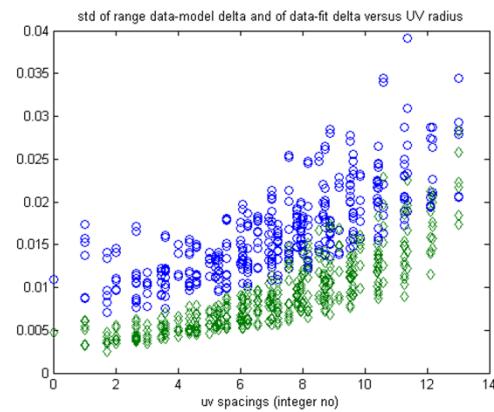
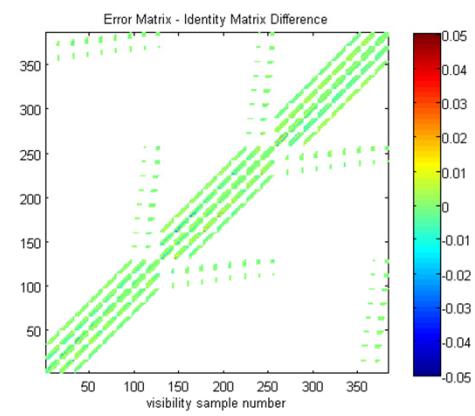
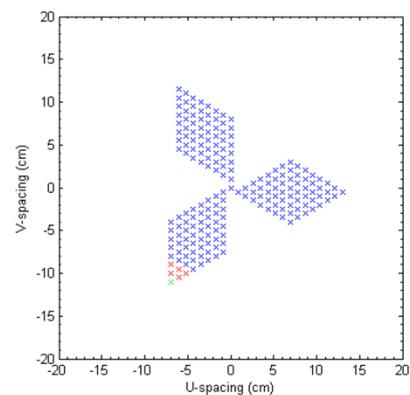
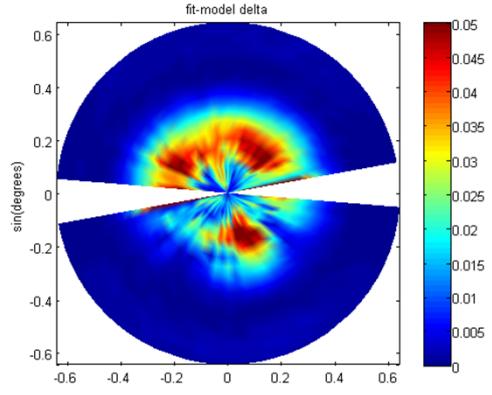
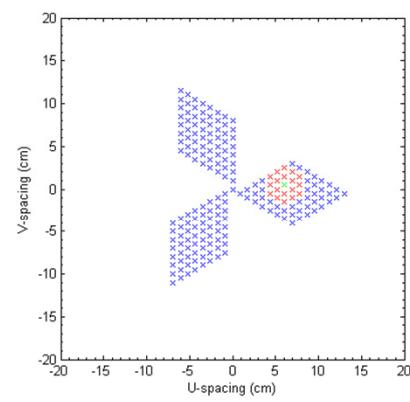
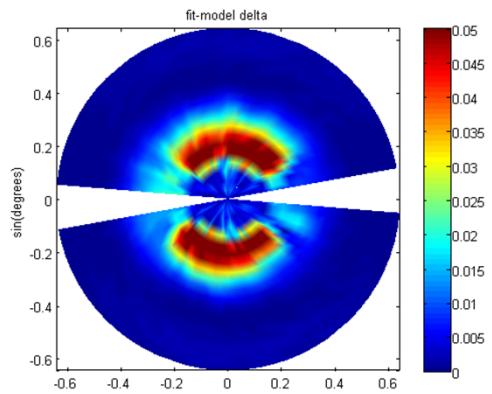
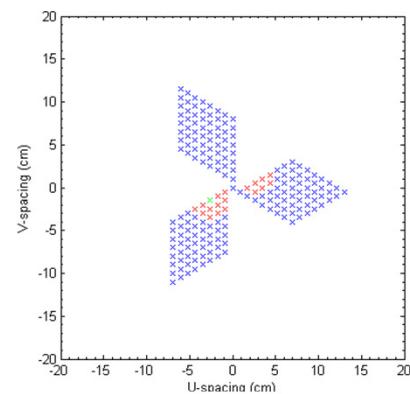
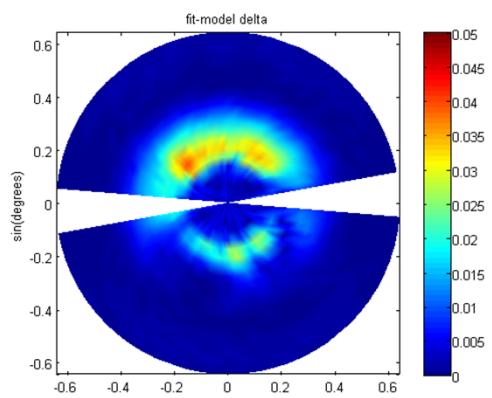
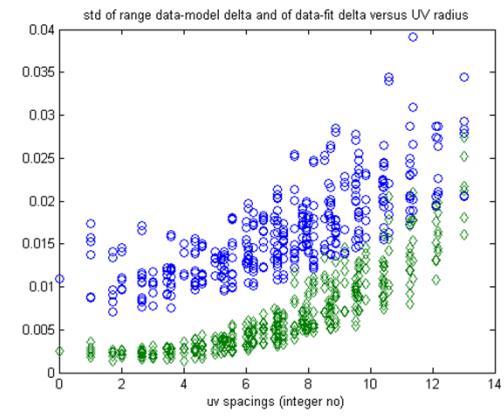
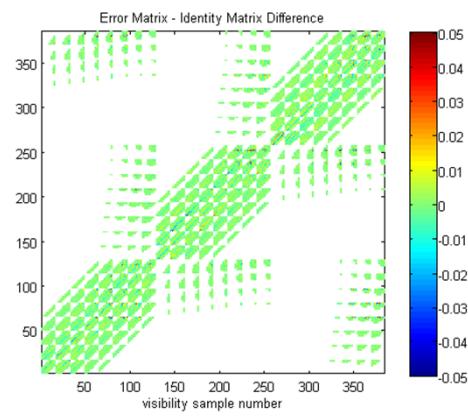
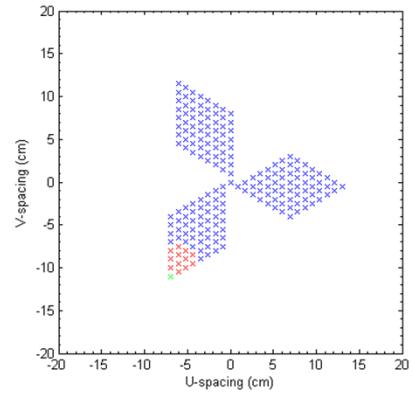
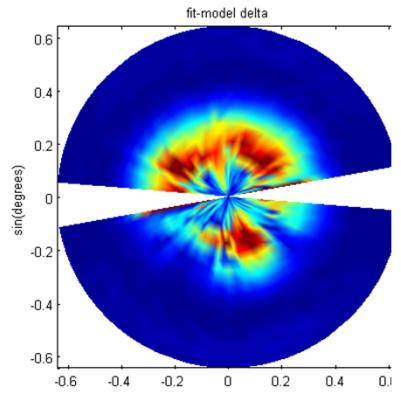
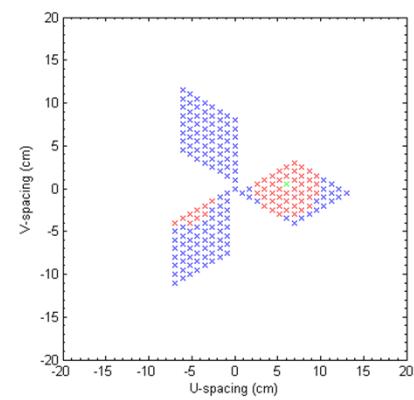
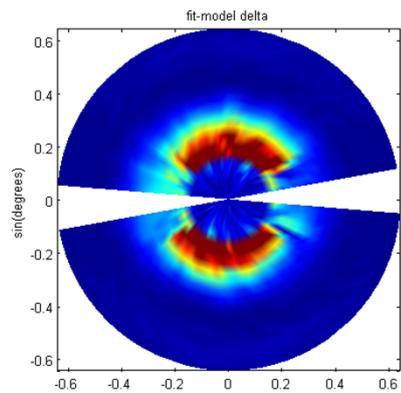
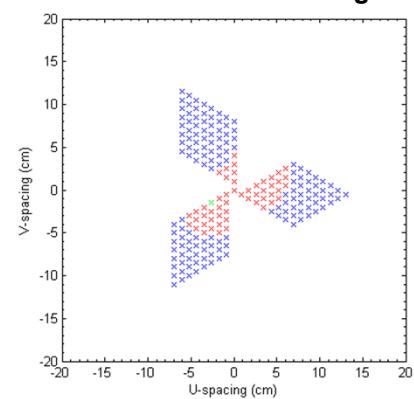
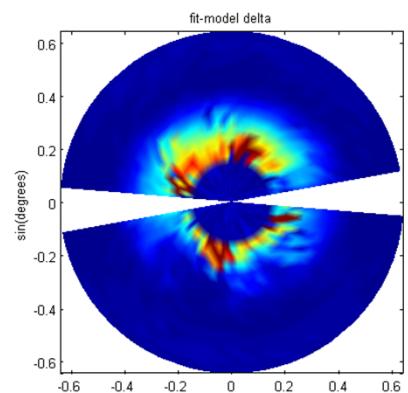
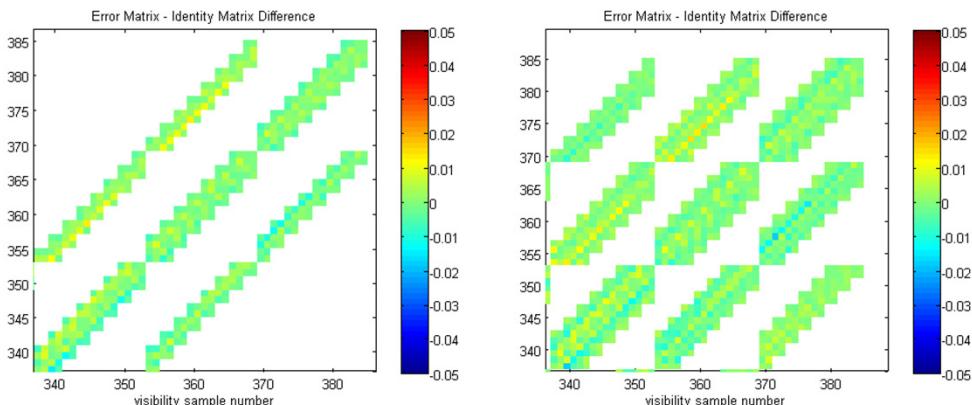
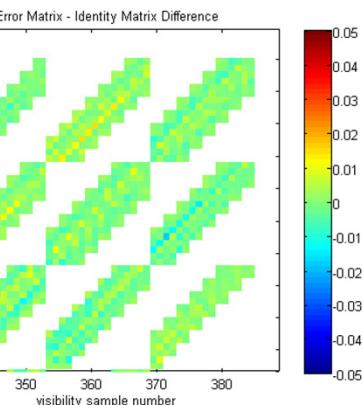


Figure 3d:Nn <= 110

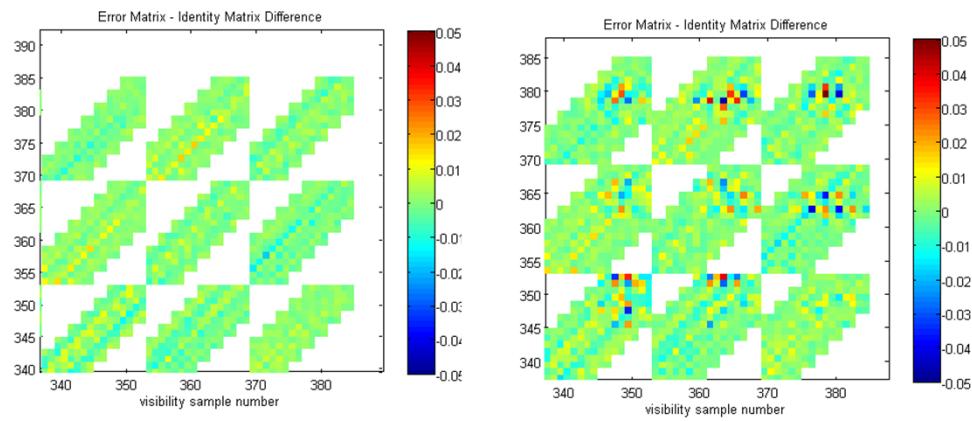




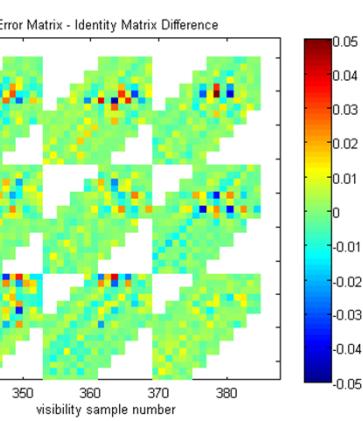
$N_n = 14$



$N_n = 38$



$N_n = 62$



$N_n = 110$

Figure 4: Expansion of error matrices computed from (6). The $N_n = 110$ case shows evidence of instability in the matrix inversion.

Figure 3e: Nn variable, based on algorithm discussed in text

